# CONTRIBUTIONS OF THE ELECTRONIC SEMICONDUCTOR TECHNOLOGY TO THE U.S. AND SOME OTHER PARTS OF THE WORLD ECONOMY*

by
MICHAEL BORETSKY

## INTRODUCTION

I was asked to give a brief overview of the contribution the electronics technology has made to the United States economy. I was also told that whatever international comparisons I could make would be welcome. Well, electronics technology goes back to the turn of the century--the time Marconi invented his radio. Any attempt to cover the eighty or so years that have gone by since then would obviously require a rather heroic effort, especially so if one were to try to do it in the time usually allowed for a presentation in such conferences as this--some 45 minutes or so.

I think, however, that assuming that I have 45 minutes or so for my presentation, I can share with you a number of, what I think are, very instructive observations regarding the contributions the electronic semiconductor technology has made to the U.S. economy since about 1958, that is, the time when the initial transitor technology was already "mastered," the year in which Jack Kilby of

---

*Text of the lecture delivered at the CESES International Seminar on "Microelectronics and Telecommunications: East and West" in Milan, Italy, on October 1, 1981. Dr. Michael Boretsky is Adviser to the Assistant Secretary for International Economic Policy in the U.S. Department of Commerce and Research Professor of Economics and Business at the Catholic University of America in Washington, D.C. The views expressed in this lecture are those of the author and they are not necessarily shared by the U.S. Government or the Catholic University of America.

Texas Instruments invented the integrated circuit, the year in which the U.S. computer industry introduced its first second-generation computer (PHILCO 2000), and, most importantly, the year for which we began getting reasonably good data for the electronics-related industries. I think I can also share with you a few observations of how this technology seems to be diffusing throughout the world, and, at the end, if the time permits, share with you also a few ideas as to what is likely to happen in or around this technology in the near future, say, in the next 5 to 10 years.

Before I start giving you these observations, however, let me make one more introductory remark regarding the nature of the semiconductor technology. For at least four reasons, this technology has most probably had no precedence in the history of mankind.

First, unlike other technologies, this technology is for all practical purposes strictly U.S.-made. Of the 19 pivotal innovations from which this technology evolved, all but one originated in the United States (see Appendix), and of the 39 "significant" innovations--all but two originated in the United States.[1] The pivotal innovations obviously include such things as the initial replacement of the vacuum tube by a transistor (Bell Laboratories, 1947) integrated circuits (Texas Instruments, 1958), and the invention of the "all-mighty" microprocessor (Intel Corporation, 1970).

---

[1]See U.S. Department of Commerce, International Trade Administration, Office of Producer Goods, A Report on the Semiconductor Industry, September 1979, p. 100

Second, unlike all other technological advances that preceded this technology, this technology enhances not only the human muscle and/or permits humans to move around easier, but it also enhances the human mind.

Third, unlike all other technological advances which have affected only certain people and/or certain things, this technology affects or will affect everybody and everything.

Fourth, this technology seems to have few if any bad environmental side effects. Some people seem to think that although this technology does not have any bad environmental side effects, it has the potential of becoming a perfect oppression tool of the Orwellian "big brother." So far, however, the evidence to this effect is too scarce for a systematic analysis of this potentiality, let alone for the analysis of such a reality.

Bearing these qualitative characteristics in mind, let me turn now to the kind of impact this technology has had on the U.S. economy.

## THE CONTRIBUTIONS OF THE SEMICONDUCTOR TECHNOLOGY TO THE U.S. ECONOMY

For the purpose of assessing these contributions I assume that the semiconductor electronics technology affects the economy entirely, or at least almost entirely, through the suppliers of computing, calculating and accounting machines and related equipment, the suppliers of telecommunications equipment, and the suppliers of electronic components and accessories.
Had there been no semiconductor technology, some of these suppliers would not have been in the business they are in (such as suppliers specializing in semiconductor components), and those who would have been in this business anyway would have grown no more than

the total private business economy. In other words, all growth of the industries in question here, and particularly so if this growth is higher than the growth of the total private business economy, is assumed to be the function of the semiconductor technology and the progress made therein. For the sake of brevity I label the set of industries so affected by the semiconductor technology as the electronics-dependent sector.[2]

In making this assessment I have focussed on the sector's contribution to the private business economy's real growth in output and employment, growth in productivity, its impact on the economy's inflation, and its role in the economy's foreign trade. The timespan considered is the entire period from 1958 to 1980 and the shorter post-microprocessor period from 1972 to 1980. The results of this assessment are summarized in considerable detail in my handout in the five page table designated as #1. The highlights of this assessment would seem to be as follows:

(1) From 1958 to 1980 the electronics-dependent sector grew on the average by 11.2 percent per year, more than three times as fast as the entire business economy; and from 1972 to 1980 by 16.8 percent per year, more than six times as fast as the entire

[2] The alternative approach for making such estimates would be to assume that without the progress in the semiconductor technology the industries in question here ("the electronics-dependent sector") would have grown at the same rate as all other industries in the private economy except themselves. It so happens that estimates consistent with this assumption suggest even somewhat greater contributions of the progress in the semiconductor technology to the growth of the total private business economy than the estimates based on the preceding assumption. Due to space limitations I abstain from producing here these alternative estimates. Readers wishing to do do, however, can readily produce them themselves by appropriately recomputing the figures presented in Table 1.

business economy. Looking at these growth disparities from another angle--the increase in this sector's constant-dollar value of output from 1958 to 1980 amounted to 13.1 percent of the increase in similarly defined output of the entire private business economy and from 1972 to 1980, to 29 percent.[3]

Moreover, I view this huge contribution as minimum because the data I used for its calculation were derived from the sector's domestic operations only. In addition to its domestic operations, the sector has foreign-based income entering the private economy's GNP. In 1977, the sector's net income derived from foreign (direct) investments amounted to about $1.9 billion, or 3.5 percent of its domestic sales net of multiple counting, the measure I use in valuing the sector's output.

(2) The sector's contribution to the business economy's growth in employment amounted to 3.0 percent in 1958-1980 and 3.7 percent in 1972-1980--when only the growth in the sector's direct employment is considered. However, if the sector's direct and indirect employment is considered, the sector's contribution to the total business economy's growth in employment amounted to 6.6 percent in 1958-1980 and to 8.4 percent in 1972-1980.

(3) The sector's most dramatic contribution to the entire business economy would seem to have been in the area of (labor) productivity growth for two reasons--the sector's own very rapid

---

[3]Relating the sector's growth in output to that of total of manufacturing only, both defined in an identical way, the increase in the sector's value of output from 1958 to 1980 represented 25 percent of the increase in the output of total manufacturing, and 63 percent of the increase from 1972 to 1980.

growth (7.5 percent per year in 1958-1980 and 11.3 percent in 1972-1980) and a very low growth in the entire business economy (1.4 percent per year in 1958-1980 and 2/10 of one percent in 1972-1980). The result of these growth disparities was that from 1958 to 1980 the <u>increase in the sector's real value of output on account of productivity</u> amounted to 24 to 25 percent of so defined increase of output of the entire business economy; and from 1972 to 1980, to as much as 324 to 339 percent. Note that such contribution, in excess of 100 percent, obviously means that other sectors comprising the private business economy made a negative contribution, that is, their productivity declined during the period in question.

Please, note also that these contributions to the economy's productivity growth represent the sector's <u>direct</u> contribution only. In addition, computers and other electronics-related equipment are believed to generate increased productivity growth also in the users' industries. Unfortunately, however, the extent of this indirect or secondary impact cannot be readily ascertained. In the communications industry, the most intensive user of computers and other electronic devices, output per person grew in 1958-1979 by 5.9 percent per year, and in 1972-1979 by 6.3 percent, that is, very much faster than in the total private economy. This suggests that computers and other electronic devices must have played a role in the rapid productivity growth in this industry. In finance, insurance and the real estate industry, another heavy user of computers, however, output per person employed grew by 1 percent per year in 1958-1979, and by only 4/10 of 1 percent in 1972-1979. Moreover, there are many firms and, probably even major industries, where computers are being used only to produce "printouts" which have no positive impact on either the quality of management's decisions and increased profits, or generally greater productivity of manpower, thus constituting a drag on rather than stimulus to productivity growth. All of this obviously implies that the electronics-dependent sector's indirect impact on the private economy's productivity growth has not been as great as is generally assumed and, in my judgment, it has most certainly been much smaller than the direct one.

In this connection, we obviously must bear in mind that however great has been this sector's total contribution to the economy's productivity growth over the period we are discussing here, it has been, as I recently argued elsewhere,[4] unable to offset the weakness in other segments of the economy and to prevent the drastic decline in the total economy's productivity growth we have been witnessing since the mid-1960's.

(4) I estimate that in the 1958-1980 period as a whole the sector's price deflator was increasing at an average rate of about one-half of one percent, but the whole increase actually took place in 1958-1972; and from 1972 to 1980 this sector's price deflator was declining at an average rate of 1.3 percent per year. The private economy's implicit GDP deflator, however, was increasing at an average annual rate of 4.4 percent in 1958-1980 and 7.5 percent in 1972-1980. These disparities imply that the electronics-dependent sector was a powerful retarder of the economy's inflation. I estimate that from 1972 to 1980 the sector's dollar value of output

---

[4]See Michael Boretsky, "The Role of Innovation," Challenge, November-December 1980, pp. 9-15.

on account of inflation increased by a negative value of \$8.4 billion (-\$8.4), whereas the dollar value of output of the entire private business economy on account of inflation increased by \$899.3 billion. Thus the electronics-dependent sector's retardation was equivalent to about 9/10 of one percent (-0.9 percent). This is tantamount to saying that had there been no retardation of inflation by the electronics-dependent sector, the private economy's annual rate of inflation would have been almost one percentage point higher than it actually was.

(5) Finally, the electronics-dependent sector has also been a positive, though, comparatively speaking, somehwhat weak force in U.S. foreign trade. Since 1967 the sector's trade surpluses ranged from \$200 million to as much as \$3.3 billion, but in most of the years it was less than half of the upper range. The reason for the sector's modest performance in U.S. foreign trade is obviously the sector's large operations, meaning production and sales, overseas. To a degree these foreign operations are substitutes for exports, but, as noted earlier, they earn profits for the corporations and these, when repatriated, support the country's balance of payments as well as increase national income. In 1977, the sector's operations overseas represent about 40 percent of the domestic operations, and net income derived from these operations amounted to about \$1.9 billion, equivalent to 3.5 percent of the sector's domestic sales net of multiple counting.

## DIFFUSION OF THE SEMICONDUCTOR TECHNOLOGY TO THE REST OF THE WORLD

From what we know, the diffusion of the semiconductor technology has been extremely rapid, at least in comparison with the speed of diffusion of other technologies, but highly uneven.

Based on the 1980 data for production, consumption, and apparent trade balances in semiconductor devices, compiled by the American Semiconductor Industry Association, summarized in Table 2, Japan's output of electronic semiconductors constituted about 35 percent and domestic consumption about 39 percent of the United States. By 1980, Japan also had a foreign trade surplus in these products amounting to about half a billion dollars. Inasmuch as Japan's 1980 gross domestic product, valued in purchasing power equivalents, amounted to about 35.4 percent of the United States, it implies that, in terms of the production of semiconductors per dollar's worth of GDP, Japan was by 1980 on a par with the United States. In terms of consumption of the devices (both for domestic and foreign customers), it was even slightly ahead of the United States.

Europe's output of semiconductors in 1980 is estimated to have amounted to about 19 percent of the United States and consumption to about 46 percent. Europe was also a heavy importer of these devices (largely from the United States). Since Europe's GDP, properly valued, is of about the same magnitude as that of the United States, the figures imply that there is substantial gap in "mastery" of this technology between Europe and the United States. Its output per dollar's worth of GDP amounts to less than 20 percent of the United States and its consumption to less than 50 percent. Moreover, since U.S. companies are heavily involved in both the production and consumption of semiconductors in Western Europe, the genuine European "mastery" of this technology must be even lower than these figures nominally indicate.

The figures in the table indicate that the 1980 output of the semiconductors in all other countries amounted to only 3.9 percent of the United States, and their consumption to only about 16 percent. Since the aggregate GNP of these countries is believed to be somewhat greater than that of the United States, their "mastery" of this technology must be viewed to be in an infancy stage, and in most uses it is probably nonexisting.

The data on comparative output of computers and related equipment given in Table 3 imply relatively better European mastery of this technology vis-a-vis both the United States and Japan, but overall the gap is still there, especially so since more than one-half of the European output of computers is known to be accounted for by IBM and other U.S. companies operating in Europe. Note that of the four European countries represented in the table, I regret to say, Italy has the poorest performance.

Assuming the figures in this table are reasonably correct, one must also note Japan's considerably lower standing in relative production of computers and, hence, "mastery" of the whole gamut of computer-related technologies, than in the mastery of the semiconductor technology as such (i.e., "making chips").

For the kind of broad assessment I am trying to convey to you, however, the most revealing data seem to be those on the country-origin of patents issued from 1963 to 1979 by the U.S. Patent and Trademark Office on the area of electronic integrated circuit structure and microelectronic processing devices (central processing units and other systems) which the U.S. Department of Commerce published last February. The reasons for the importance of these data are: (1) Because of the importance of the U.S. market for innovations in these two critical areas of semiconductor technology, most, if not all, important United States and foreign inventions in these areas are being patented in the United States. (2) A relative number of patents obtained by a country in these two areas of technology is most probably an accurate representation of the entire area of semiconductor technology. (3) Patented inventions, much better than any other indicators, reflect the respective countries' genuine effort at improving their know-how of a particular technology. (4) The trend in each country's effort in this respect has greater predictive power for the future than any other data related to this technology. These data are summarized in Table 4.

As I see it, these data warrant the following conclusions:

(1) In the aggregate, foreign countries not only still lag behind the United States in the application of the semiconductor technology as was indicated in the preceding two tables, but they also still lag in their level of effort to improve the existing stock of know-how related to this technology.

(2) The foreign countries' gap in the level of effort to improve the existing technology relative to the United States, however, is narrowing. The bulk of this narrowing is produced by the Netherlands and, particularly, Japan.

(3) Throughout the period, however, the greatest effort to improve the existing technology per dollar's worth of GDP was not that of the United States, but that of the Netherlands. By now this U.S. effort seems to be exceeded also by Japan.

(4) In terms of per dollar's worth of GDP, all European counrtries' level of effort at expanding the frontiers of this technology, except for the Netherlands, would seem to be only about 25 percent of the U.S. level, and even less than that relative to Japan.

(5) Of all the countries specifically listed in the table, with the exception of the USSR, Italy seems to be exerting both the least effort and to be making absolutely no relative progress as time goes by.

Finally, I must also comment, at least briefly, on the nature of the massive drive undertaken by Japan, and apparent in these data, to expand the frontiers of this technology. This drive is obviously consistent with the longrange plan to transform its industry into a knowledge-based enterprise and to make Japan an information-based society, and in the process of doing all of this, to replace the United States as the world's technological leader.[5] I am told that "the plan" is nothing more than a far-fetched expression of wishful thinking on the part of MITI and of some other Japanese agencies, and that Japan has no capacity for a world leadership position because it is not a risk-taker and, therefore, cannot be fundamentally innovative. To prove this thesis, reference is usually made to the flow of hundreds of patents,underlying the data for Japan in Table 2,most of which merely improve on and/or extrapolate the fundamental discoveries produced in other countries and neither of which came so far as to become a really pivotal innovation. Whether or not this will be so, only history will tell. What they are doing, however, produces for them the kind of competitive advantage on the world scene that most other countries, especially in Europe, will never be able to match, let alone to overcome.

## WHAT'S AHEAD IN THE SEMICONDUCTOR ELECTRONIC TECHNOLOGY?

In a lecture like this I obviously cannot attempt to make a full-fledged forecast of what is going to happen in the general area of semiconductor technology and when. But instead of concluding my lecture at this point I thought I would share with

---

5For a brief summary of the basis thrust of this plan, see "Vision for the 1980s," The Oriental Economist, November 1979, pp. 12-16

-- "The microprocessor is free, if you buy its memory device,"

-- "The minicomputer is free, if you buy its peripherals," and

-- "The main frame computer is free, if you buy the necessary software."

• The evolution in the technology of data processing of the past two decades will continue in the 1980's with:

-- exponential growth in storage and reliability of the central processing units (CPUs) accompanied by increasing cost effectiveness, and decreasing size of the units;

-- exponential growth in the use of microprocessors, especially in the industrial sector (for automation, robots, etc.); and

-- increasing functionality of the systems built into the hardware.

• In telecommunications, digital transmission will be the technology of the future. For this reason data processing and telecommunications industries will become progressively undistinguishable.

• Presently such distinguishable industries as manufactures of computers, manufacturers of office equipment, manufacturers of communications equipment and manufacturers of semiconductor components will become progressively undistinguishable.

- Japan will become progressively visible on the world scene in the production, marketing and servicing of all the equipment which this new integrated industry will entail.

All of these observations imply that, at the minimum, we should expect continuation of the past trends. It is conceivable, however, that in at least some respect, Japan's visibility on the world scene, might cause us to exclaim:

"YOU AIN'T SEEN NOTHING YET!"

TABLE 1

THE CONTRIBUTIONS OF THE SEMICONDUCTOR ELECTRONICS TECHNOLOGY[a] TO THE U.S. ECONOMY, 1958-1980

| Item and Measure | Estimate |
|---|---|
| Growth of the electronics-dependent industries (sector)[a] compared to the growth of total private business economy: | |
| 1a. Average annual growth in real output of the electronics-dependent sector,[b] % per year | |
| • 1958-1980 | 11.2 |
| • 1972-1980 | 16.8 |
| 1b. Average annual growth in real output (GNP) of the total private business economy, % per year | |
| • 1958-1980 | 3.6 |
| • 1972-1980 | 2.7 |
| 1c. Difference between (1a) and (1b), percentage points | |
| • 1958-1980 | +7.6 |
| • 1972-1980 | +14.1 |
| Contribution of the growth of the electronics-dependent sector to the growth of the total private business economy: | |
| 1aa. The increase in the real annual output of the electronics-dependent sector,[b] $Billion (1972) | |
| • From 1958 to 1980 | 81.1 |
| • From 1972 to 1980 | 63.8 |
| 1bb. Increase in the private business economy's GNP, $Billion (1972) | |
| • From 1958 to 1980 | 617.8 |
| • From 1972 to 1980 | 219.7 |
| 1cc. Ratio of (1aa) to (1bb), % | |
| • From 1958 to 1980 | 13.1 |
| • From 1972 to 1980 | 29.0 |
| Growth in employment of or induced by the electronics-dependent sector compared to the growth of employment in the total private business economy: | |
| 2a. Average annual growth in the direct employment of the electronics-dependent sector, % per year | |
| • 1958-1980 | 3.7 |
| • 1972-1980 | 4.9 |
| 2b. Average annual growth in total employment induced by the electronics-dependent sector (direct plus indirect),[c] % per year | |
| • 1958-1980 | 4.3 |
| • 1972-1980 | 5.7 |
| 2c. Average annual growth of employment in the private business economy, % per year | |
| • 1958-1980 | 2.3 |
| • 1972-1980 | 2.5 |
| 2d. Difference between (2a) and (2c), percentage points | |
| • 1958-1980 | +1.4 |
| • 1972-1980 | +2.4 |
| 2e. Difference between (2b) and (2c), percentage points | |
| • 1958-1980 | +2.0 |
| • 1972-1980 | +3.2 |

| Item and Measure | Estimate |
|---|---|
| 2. Contribution of the electronics-dependent sector to the growth of total employment in the private business economy: | |
| 2aa. Increase in the electronics-dependent sector's direct employment, thousand | |
| • From 1958 to 1980 | 829 |
| • From 1972 to 1980 | 474 |
| 2bb. Increase in the private business economy's employment on account of electronics-dependent sector's business (direct plus indirect),[c] thousand | |
| • From 1958 to 1980 | 1,799 |
| • From 1972 to 1980 | 1,074 |
| 2cc. Increase in the private business economy's total employment, thousand | |
| • From 1958 to 1980 | 27,406 |
| • From 1972 to 1980 | 12,801 |
| 2dd. Ratio of (2aa) to (2cc), % | |
| • From 1958 to 1980 | 3.0 |
| • From 1972 to 1980 | 3.7 |
| 2ee. Ratio of (2bb) to (2cc), % | |
| • From 1958 to 1980 | 6.6 |
| • From 1972 to 1980 | 8.4 |
| 3. Growth in labor productivity in the electronics-dependent sector compared to the productivity growth in the total private business economy: | |
| 3a. Average annual growth in the electronics-dependent sector's output per person employed (directly in the sector), % per year | |
| • 1958-1980 | 7.5 |
| • 1972-1980 | 11.3 |
| 3b. Average annual growth in the private business economy's output per person employed, % per year | |
| • 1958-1980 | 1.4 |
| • 1972-1980 | 0.2 |
| 3c. Difference between (3a) and (3b),[d] percentage points | |
| • 1958-1980 | +6.1 |
| • 1972-1980 | +11.1 |

TABLE 1
THE CONTRIBUTION OF ELECTRONICS
TECHNOLOGY TO THE U.S. ECONOMY, 1958-1980--Cont. (3)

| Item and Measure | Estimate |
|---|---|
| 3A. Contributions of the electronics-dependent sector to the growth of labor productivity in the private business economy: | |
| 3aa. Increase in electronics-dependent sector's real output on account of productivity growth considering the sector's direct employment only, $Billion (1972) | |
| • From 1958 to 1980 | 70.3 |
| • From 1972 to 1980 | 51.8 |
| 3bb. Increase in the electronics-dependent sector's real output on account of productivity growth considering the sector's direct and indirect employment, $Billion | |
| • From 1958-1980 | 67.9 |
| • From 1972-1980 | 49.5 |
| 3cc. Increase in the total private business economy's GNP on account of productivity growth, $Billion (1972) | |
| • From 1958-1980 | 284.4 |
| • From 1972-1980 | 15.3 |
| 3dd. Ratio of (3aa) to (3cc), % | |
| • From 1958-1980 | 24.7 |
| • From 1972-1980 | 338.6 |
| 3ee. Ratio of (3bb) to (3cc), % | |
| • From 1958 to 1980 | 23.9 |
| • From 1972 to 1980 | 323.5 |
| 4. Inflation in the electronics-dependent sector compared to that in the total business economy: | |
| 4a. Estimated average annual rate of growth of deflator for output of the electronics-dependent sector, % per year | |
| • 1958-1980 | 0.5 |
| • 1972-1980 | -1.3 |
| 4b. Average annual rate of growth of deflator for the private business economy's GNP, % per year | |
| • 1958-1980 | 4.4 |
| • 1972-1980 | 7.5 |
| 4c. Difference between (4a) and (4b), percentage points, | |
| • 1958-1980 | -3.9 |
| • 1972-1980 | -8.8 |
| 4A. Contribution of the electronics-dependent sector to the retardation of inflation in the private business economy: | |
| 4aa. Increase in the dollar value of the electronics-dependent sector's output on account of inflation, $Billion | |
| • From 1958 to 1980 | -6.9 |
| • From 1972 to 1980 | -8.5 |
| 4bb. Increase in the dollar value of the private business economy's total output on account of inflation, $Billion | |
| • From 1958 to 1980 | 1,058.1 |
| • From 1972 to 1980 | 899.3 |
| 4cc. Ratio of (4aa) to (4bb), % | |
| • From 1958 to 1980 | -0.7 |
| • From 1972 to 1980 | -0.9 |

TABLE 1

THE CONTRIBUTIONS OF THE SEMICONDUCTOR ELECTRONICS TECHNOLOGY TO THE U.S. ECONOMY, 1958-1980--Cont. (4)

| Item and Measure | Estimate |
|---|---|
| Contribution of the electronics-dependent sector to the economy's balance of trade: | |
| o The electronics-dependent sector's balance of trade, $Billion | |
| 1967 | 0.6 |
| 1972 | 0.4 |
| 1977 | 1.3 |
| 1978 | 0.2 |
| 1979 | 1.5 |
| 1980 | 3.3 |

[a] The semiconductor electronics technology affects the economy entirely or almost entirely through supply of computing, calculating, and accounting equipment (industries SIC 3573 and 3574), telecommunication equipment (SIC 3651, 3661 and 3662) and the supply of electronic components (SIC 367). I label the set of these industries as electronics-dependent sector. For the purpose of the present analysis I assume that the growth of this sector has been entirely or almost entirely a function of the improvements or progress in the semiconductor technology.

[b] The real output of the electronics-dependent sector is measured here by its sales net of multiple counting valued in 1972 dollars (which from production point of view, is equivalent to the sector's value added plus the net cost of raw materials, energy and other purchased supplies). The extent of multiple counting is calculated from input/output tables (available for 1958, 1963, 1967, and 1972).

The sector's contribution to the private economy's GNP as calculated here is somewhat understated because the data used here are derived from the sector's domestic operations only. In addition, the sector obtains substantial income from its large direct investments abroad. In 1977 its sales abroad amounted to about 40 percent of the domestic and its net income derived from foreign direct investment amounted to $1.9 billion, or 3.5 percent of its domestic sales net of multiple counting.

[c] Direct employment in the sector is regularly reported in official statistics. The indirect employment is approximated via input/output and related employment procedure.

[d] Computers and other electronics-related equipment tend to generate increased productivity growth also in the users' industries. However, the extent of this impact cannot be readily ascertained. In the communications industry, the most intensive user of computers and other electronic devices, output per person grew in 1958-1979 by 5.9 percent per year, and in 1972-1979 by 6.3 percent, that is, very much faster than in the total private economy, and this suggests that computers and other electronic devices played a role in this rapid growth. In finance, insurance and real estate industry, another heavy user of computers, however, output per person employed grew in 1958-1979 by 1 percent per year, and in 1972-1979, by 4/10 of 1 percent only. There are many firms and, probably, even major

TABLE 3

THE CONTRIBUTIONS OF THE S[illegible] ELECTRONICS TECHNOLOGY TO THE U.S. ECONOMY, 1958-1980--Cont. (5)

industries, where computers are being used only to produce "printouts" with no positive impact on either the quality of management's decisions and better profits, or generally greater productivity of manpower, thus constituting a drag on rather than stimulus of productivity growth.

[e] In calculating the electronics-dependent sector's deflator, I used the relevant data from the Bureau of Economic Analysis (BEA) and the BLS except for the deflator for computers and related peripherals. For computers and related peripherals I used a deflator index declining by 10 percent per year, in line with a rather persuasive evidence to that effect, rather than the BEA index which does not change at all (assumed to be 100 throughout the time period).

Sources: U.S. Department of Commerce--Bureau of Economic Analysis, Bureau of Census and Bureau of Industrial Analysis; and Department of Labor, Bureau of Labor Statistics.

TABLE 2

COMPARATIVE OUTPUT, CONSUMPTION AND TRADE BALANCES OF ELECTRONIC SEMICONDUCTORS IN 1980 AS ESTIMATED BY (AMERICAN) SEMICONDUCTOR INDUSTRY ASSOCIATION

| Country and/or Region | Output (Production | | Consumption | | Apparent Trade Balance | |
|---|---|---|---|---|---|---|
| | $ Billion[a] | % of U.S. | $ Billion[a] | $ of U.S. | $ Billion[a] | % of Consumption |
| United States | 10.2 | 100.0 | 8.0 | 100.0 | +2.2 | -- |
| Europe | 1.9 | 18.6 | 3.7 | 46.3 | -1.8 | 48.6 |
| Japan | 3.6 | 35.3 | 3.1 | 38.8 | +0.5 | -- |
| Other | .4 | 3.9 | 1.3 | 16.3 | -0.9 | 69.2 |
| The World (Western) | 16.1 | 157.8 | 16.1 | 201.3 | -- | -- |

[a]The dollar values were apparently derived by multiplying the underlying values in foreign currencies by official exchange rates rather than the relative domestic purchasing power equivalents of these currencies for these products. The relative physical magnitudes of the respective outputs, consumption and trade balances might, therefore, be somewhat different than the percentages shown in the table.

Source: Semiconductor Industry Association, The International Microlectronic Challenge (Advanced Copy), March 1981, p. 27

TABLE 3

COMPARATIVE OUTPUT OF COMPUTERS AND RELATED EQUIPMENT (PERIPHERALS) VALUED IN DOLLARS OF (ECONOMY-WIDE) ROUGHLY COMPARABLE PURCHASING POWER, SELECTED YEARS 1970-1980

| Item and Country | 1970 | 1975 | 1976 | 1977 | 1978 | 1979P | 1980P |
|---|---|---|---|---|---|---|---|
| A. Comparative Absolute Level of Output: | | | | | | | |
| United States | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| West Germany | 15.0 | 1.26 | 12.7 | 13.7 | 12.0 | 10.6 | 10.0 |
| France | na | na | na | 21.1 | 19.2 | 17.5 | 16.1 |
| Italy | na | na | na | na | 4.5 | 4.4 | 3.9 |
| United Kingdom | na | 17.8 | 13.1 | 11.3 | 10.3 | 9.4 | 7.5 |
| Japan | 26.0 | 25.7 | 24.7 | 22.6 | 23.7 | 25.1 | 25.1 |
| B. Comparative Level of Output Per Dollar's Worth of GDP: | | | | | | | |
| United States | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| West Germany | 68.5 | 59.2 | 59.9 | 66.2 | 58.5 | 50.7 | 46.9 |
| France | na | na | na | 112.2 | 103.2 | 93.6 | 84.7 |
| Italy | na | na | na | na | 37.5 | 35.8 | 30.5 |
| United Kingdom | na | 83.6 | 82.9 | 72.9 | 69.1 | 63.9 | 51.7 |
| Japan | 91.5 | 80.6 | 76.5 | 70.0 | 72.5 | 74.5 | 70.9 |

P = Preliminary

Sources: Bureau of Industrial Economics, Bureau of Labor Statistics and individual country data

TABLE 4

COUNTRY-ORIGIN OF PATENTS ISSUED BY U.S. PATENT AND TRADEMARK OFFICE IN THE AREA OF ELECTRONIC INTEGRATED CIRCUIT STRUCTURE AND MICRO-ELECTRONIC PROCESSING DEVICES (CPU'S AND OTHER SYSTEMS) IN 1963-1979

| Country to Which Patents Were Issued | 1963-1979 Number of Patents | 1963-1979 % of U.S. | 1975-1979 Number of Patents | 1975-1979 % of U.S. | Number of Patents Per Dollar's Worth of GDP Relative to U.S. 1963-1979 | Number of Patents Per Dollar's Worth of GDP Relative to U.S. 1975-1979 |
|---|---|---|---|---|---|---|
| United States | 1,841 | 100.0 | 636 | 100.0 | 100 | 100 |
| All Foreign Countries | 811 | 44.0 | 400 | 62.9 | NA | NA |
| -- West Germany | 150 | 8.1 | 63 | 9.9 | 39 | 47 |
| -- France | 69 | 3.7 | 25 | 3.9 | 21 | 21 |
| -- Netherlands | 105 | 5.7 | 46 | 7.2 | 143 | 175 |
| -- Italy | 9 | 0.5 | 4 | 0.6 | 5 | 5 |
| -- United Kingdom | 71 | 3.9 | 27 | 4.2 | 23 | 27 |
| -- Japan | 380 | 20.6 | 215 | 33.8 | 80 | 106 |
| -- USSR | 5 | 0.3 | 5 | 0.8 | ... | ... |
| -- All Other | 22 | 1.2 | 15 | 2.3 | NA | NA |

... = Insignificant

Source: U.S. Department of Commerce, Patent and Trademark Office, and U.S. Bureau of Labor Statistics

APPENDIX

COUNTRY-ORIGIN OF PIVOTAL ADVANCES IN SEMICONDUCTOR ELECTRONICS SINCE 1947

| Advance | Definition | Country-Origin | Year |
|---|---|---|---|
| Transistor Effect | Basic discovery that a crystal of semiconductor material can replace a vacuum tube | U.S. | 1947 |
| Junction Transistor | Transistor whose crystal has "junctions" - planes where the type of electrical conductivity changes from positive to negative | U.S. | 1948 |
| Crystal "Pulling" | Technique for growing a single crystal of transistor quality from a molten material | U.S. | 1949/50 |
| Alloy Junction Techniques | Commercial process of forming "junctions" on crystals - of significance in the early transistor era | U.S. | 1951 |
| Field-Effect Transistor | Type of transistor in which motion of electronic charges is controlled by an imposed electrical field | U.S. | 1951/59 |
| Zone Refining | Technique for removing unwanted impurities from a crystal | U.S. | 1951 |
| Diffusion | Technique for implanting desirable impurities into a crystal | U.S. | 1954 |
| III-V Compounds | Comprising elements from groups III and IV of periodic table; used in solid-state lasers, LED's, microwave devices | Germany | 1955 |
| Oxide Masking | Important process for making integrated circuits: a crystal is covered with an oxide layer into which a pattern is etched | U.S. | 1956 |
| Thermocompression Bonding | Precision technique for attaching wires to semiconductor surfaces | U.S. | 1956 |
| Photolithography | Technique for printing microscopic patterns on surface of semiconductors to form circuits and devices | U.S. | 1957 |
| Integrated Circuits | Comprising many transistors and other circuit elements - contained in semiconductor "chips" | U.S. | 1958 |
| Planar Transistor | Transistor whose crystal is coated with oxide - the fabrication process proved important in development of integrated circuits | U.S. | 1959 |
| Epitaxy | Process for "building" a crystal of one electronic type onto a crystal of another type | U.S. | 1960 |
| Ion Implantation | Technique for implanting elements into a crystal by "bombardment" with the ionic forms of the elements | U.S. | Mid-1960's |
| Light-Emitting Diodes (LED's) | Devices that provide light for illumination or spots of light for generating display characters | U.S. | 1965 |
| Charge-Coupled Devices | Make possible more economical realization of some circuit functions, e.g., certain imaging and memory functions | U.S. | 1970 |
| Microprocessor | Logic, memory and other functions of an electronic circuit (or a microcomputer) integrated in a single "chip" | U.S. | 1970 |
| Electron-Beam Exposure System | Faster, more precise technique for defining patterns for integrated circuits | U.S. | 1974 |

Sources: Bell Labs and U.S. Department of Commerce